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Copepods of the Genus *Leptocaris* (Harpacticoida: Darcythompsoniidae) from Salt Marshes in South Korea

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ABSTRACT

Two copepod species of *Leptocaris* belonging to the family Darcythompsoniidae are recorded from sandy mud sediments of salt marshes in South Korea: *L. brevicornis* (van Douwe, 1905) and *L. trisetosus pacificus* n. ssp. The genus *Leptocaris* is newly known from Korea. *Leptocaris trisetosus pacificus* differs from the nominate subspecies in exhibiting a sexual dimorphism in setal armature of leg 3, that is, bearing an additional seta on the second endopodal segment of leg 3 in male and an allopatric geographical distribution. This paper deals with the description and systematic accounts of them with detailed illustrations.

Key words: Taxonomy, Copepoda, Harpacticoida, Darcythompsoniidae, *Leptocaris*, salt marsh, Korea

INTRODUCTION

The family Darcythompsoniidae is a characteristic copepod group, which shows considerably slender, cylindrical body. It mainly inhabits bottom sediments with high organic matter content at coastal marshes or lagoons. Lang (1944) recognized three genera in this family, *Darcythompsonia*, *Leptocaris* and *Horsiella*, but Kunz (1961) and Lang (1965) considered the latter two genera as synonymous, uniting the species within *Leptocaris* (cited from Boxshall and Halsey, 2004). The genus *Leptocaris* T. Scott, 1899 currently comprises more than 24 species. Among them, only three species are reported from the continental waters (Dussart and Defaye, 1990).

As the serial researches on the brackish-water copepods from Korea, the authors have reported *Mesochra* by Lee and Chang (2003), *Onychocamptus* by Lee and Chang (2005), *Limnocletodes* and *Kollerua* by Lee and Chang (2007), and *Nitokra koreanus* and *Ameira parvula* by Chang (2007). The authors discovered recently two species of *Leptocaris*, which were collected from the sandy mud sediments of salt marshes in South Korea. The genus *Leptocaris* is new to Korean fauna, so we herein provide the description of them with detailed illustrations.

MATERIALS AND METHODS

Materials examined in the present study were collected from coastal salt marshes and estuaries at nine localities (Fig. 1) in South Korea during the period from July, 1994 to May, 2007. Collections were made with a dipnet of 64 μm mesh. Copepods were fixed and stored in 4% buffered formalin.

Specimens were dissected and mounted in lactophenol on H-S slide (Shirayama et al., 1993), a recent variation of Cobb slide, after the treatment in a solution of 5% glycerin-95% ethyl alcohol for 1-2 days. Dissection is performed using two needles made from 0.25 mm diameter tungsten wire by electrolysis (Huys and Boxshall, 1991). Mounted specimens were observed using a differential interference contrast microscope (Olympus BX-51) equipped with Nomarski optics. All drawings and measurements were made with the aid of a camera lucida.

Type specimens are deposited in the National Institute of Biological Resources, Incheon (NIBR), Korea and in the specimen room of the Department of Biological Science, Daegu University.

Abbreviations used in the text and figure legend follow the conventional ones frequently used in the taxonomy of copepods: A1, antennule; A2, antenna; enp 1-3 or exp 1-3, the first to third endopodal or exopodal segment of each leg; Fu, caudal rami; P1-P6, first to sixth pereiopods (thoracic legs).

SYSTEMATIC ACCOUNTS

Family [1]*Darcythompsoniidae Lang, 1936
Genus [2]**Leptocaris* T. Scott, 1899
[3]***Leptocaris brevicornis* (van Douwe, 1905) (Figs. 2, 3)**

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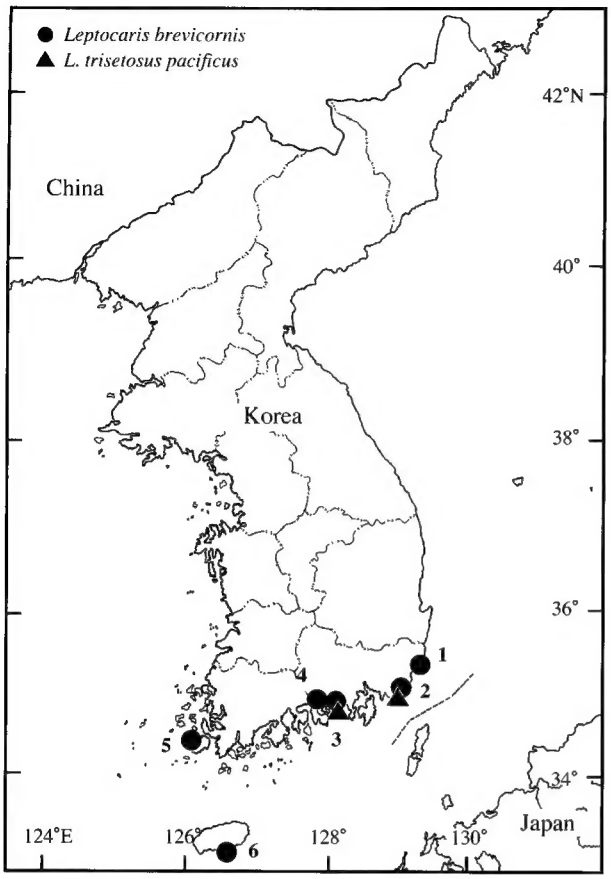

Fig. 1. A map showing collection localities in South Korea. 1, estuary of Hoiyacheon Stream, Ulsan; 2, Dadaepo, Busan; 3, estuary of Gasancheon Stream, Chukdong, Sacheon; 4, estuary of Gwangokcheon Stream, Jingyo, Hadong; 5, estuary of Sopocheon Stream, Jindo Is.; 6, Saeseom Islet, Jeju Is.

Cylindropsyllus brevicornis van Douwe, 1905, p. 437, figs. 8-10.

Horsiella brevicornis: Gurney, 1920, p. 194, figs. 5-6; Gurney, 1932, p. 314; Lang, 1948, p. 275; Borutzky, 1952, p. 410; Dussart, 1967, p. 162, fig. 56; Tai and Song, 1979, p. 299, fig. 168.

Leptocaris brevicornis: Kunz, 1961, p. 277; Lang, 1965, p. 96; Kikuchi and Yokota, 1984, p. 6, figs. 4-5; Apostolov and Marinov, 1988, p. 79, fig. 25, 1a-e; Huys et al., 1996, p. 214, fig. 84E-G; Dussart and Defaye, 1990, p. 18; Bodin, 1997, p. 42.

Material examined. 1♂, estuary of Hoiyacheon Str., Ulsan, 24 Sep. 2005 (C.Y. Chang and J.M. Lee); 2♀♀, 1♂, Dadaepo (reed marsh), Busan, 28 Sep. 2005 (C.Y. Chang, J.M. Lee and H.W. Lim); 7♀♀ (2 ovi.), 2♂♂, estuary of Gasancheon Str., Chukdong, Sacheon, 26 Apr. 2007 (C.Y. Chang, J.M. Lee and H.J. Yoon); 1♀, estuary of Gwangokcheon Str., Jingyo, Hadong, 26 Apr. 2007 (C.Y. Chang, J.M. Lee and H.J. Yoon); 3♀♀, 2♂♂, estuary of Sopocheon Str., Jindo Is., 26 Jul. 1994 (C.Y. Chang and S.J. Song); 1♀, Saeseom Islet (salt marsh), Jeju Is., 24 Apr. 2006 (C.Y. Chang).

Description. Female. Body (Fig. 2A) vermiform, cylindrical, slender, elongate, 610±30 μm (ranging 574-645 μm, N=11) in length, without clear distinction between prosome and urosome. All prosomites and urosomites except penultimate urosomite and anal somite with 2 pairs of long sesillae dorsolaterally and laterally along posterior margin; posterior margins of all somites smooth. Prosome consisting of cephalosome and 4 prosomites; distolateral margin of each prosomites not protruded. Cephalosome bell-shaped, protruding anteriorly, a little shorter than sum of next 3 prosomites; short hairs scattered throughout whole dorsal surface. Rostrum not conspicuous. Genital double-somite completely fused, with only lateral subcuticular ridge and paired short sesillae marking line of fusion, in dorsal view. Anal somite tapering posteriorly, about 1.5 times longer than wide, with paired sesillae dorsolaterally. Anal operculum a little convex, with smooth posterior margin (Fig. 2B).

Fu cylindrical, 1.65-1.86 times (mean 1.75, N=11) longer than wide, a little divergent posteriorly. Dorsal surface and medial margin smooth except dorsal or lateral caudal seta (Fig. 2B). Lateral caudal setae (caudal setae I, II) vestigial. Outer caudal seta (caudal seta III) short, locating near middle of lateral margin. Outer terminal caudal seta (caudal seta IV) slender, nearly as long as Fu. Inner terminal caudal seta (caudal seta V) well-developed, bare, about 0.4 times as long as body length; basal part not swollen. Inner caudal seta (caudal seta VI) slender, bare, a little shorter than outer caudal seta. Dorsal caudal seta (caudal seta VII) situated a little medially from middle of dorsal surface of Fu.

A1 (Fig. 2C) short, tepering distally, indistinctly 5-segmented; segment 1 armed with minute seta anterodistally; segment 2 bearing 1 row of 3 setae in dorsal surface with 2 minute setae anterodistally; segments 4 and 5 each with 1 long aesthetasc apically. A2 3-segmented; free endopod 1-segmented, bearing 7 spines and 2 terminal setae; exopod vestigial, represented by 1 small protuberance bearing 2 minute setae apically (Fig. 2D, arrow).

Mandibular palp absent. Maxillule and maxilla nearly same in shape and armature as those of next species, *L. trisetosus* (cf. Fig. 4E, F). Maxilliped completely disappeared.

P1 (Fig. 2E), exopod 3-segmented; endopod 2-segmented, much shorter than exopod; coxa armed with 1 row of sharp spinules at distolateral corner; basis with 1 medial seta, its tip exceeding middle of enp 1; enp 1 a little longer than

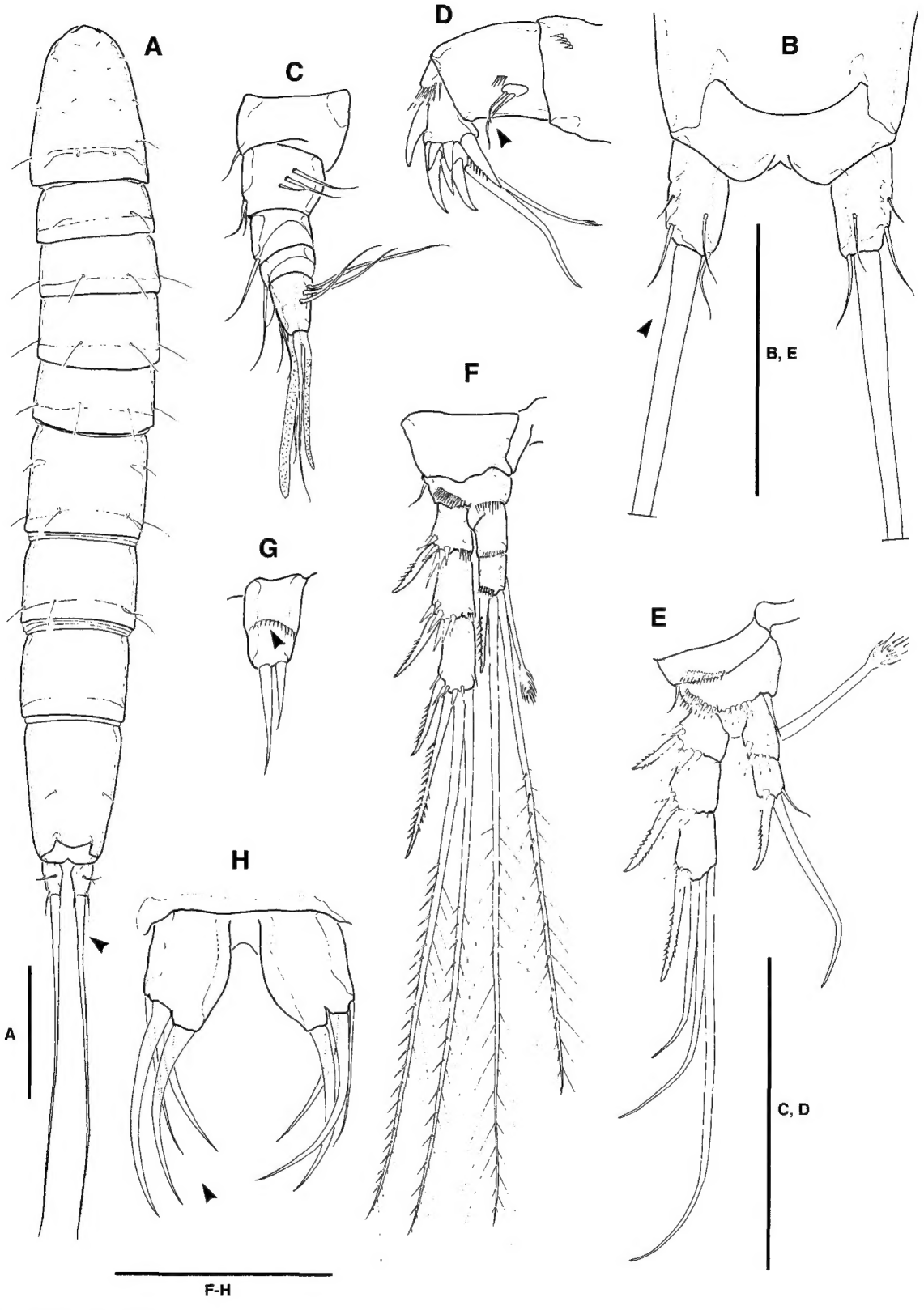

Fig. 2. *Leptocaris brevicornis* (van Douwe). A-G, female: A, habitus, dorsal; B, anal somite and Fu, dorsal; C, A1; D, A2; E, P1; F, P2; G, P5. H, male P5. Scale bars=100 μm (A), 50 μm (B-H).

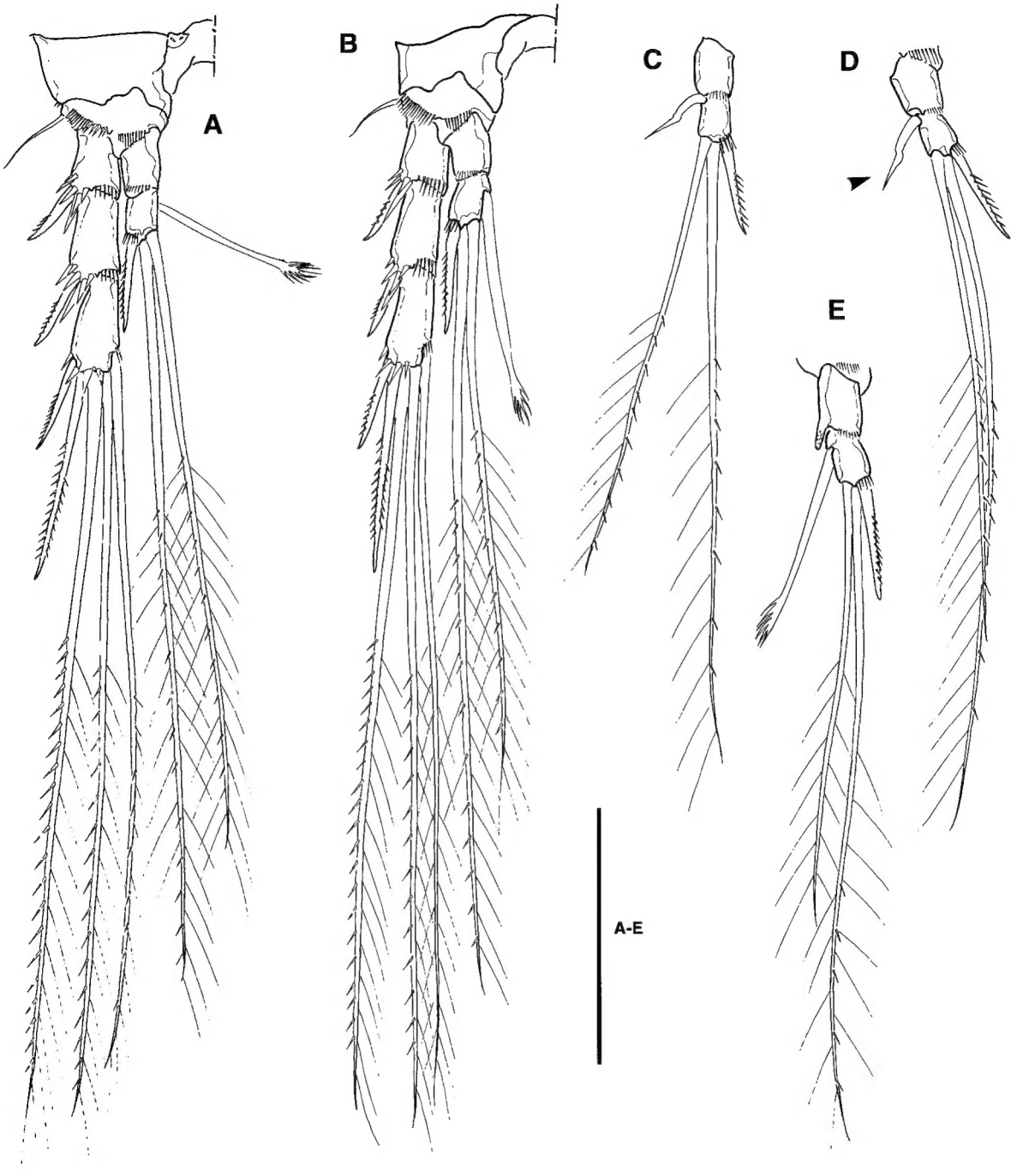

Fig. 3. *Leptocaris brevicornis* (van Douwe). A-B, female: A, P3; B, P4. C-E, male: C, P2 endopod; D, P3 endopod; E, P4 endopod. Scale bar=50 μm (A-E).

enp 2, bearing 1 stout, terminally pinnate inner seta, pointing anteromedially; enp 2 with 1 short inner distal seta, 1 long apical seta and 1 outer spine; exp 2 without inner seta; exp 3 with 1 outer spine and 3 long setae.

P2-P4 (Figs. 2F, 3A, B), exopods 3-segmented; endopods 2-segmented; enp 1 lacking inner seta; enp 2 bearing 1 outer distal spine, 2 long apical setae (inner one about 80-86% as long as outer one), 1 terminally pinnate inner seta. Seta and spine arrangements of P1-P4 as follows (Arabic numerals representing setae, while Roman numerals indicating spines):

P1	basis 1-1	exp I-0; I-0; I,2,1	enp 0-1; I,1,1
P2	basis 1-0	exp I-0; I-0; II,2,0	enp 0-0; I,2,1
P3	basis 1-0	exp I-0; I-0; II,2,1	enp 0-0; I,2,1
P4	basis 1-0	exp I-0; I-0; II,2,1	enp 0-0; I,2,1

P5 (Fig. 2G) small, represented by small protuberance with 2 bare setae distally; inner seta about 1.5 times longer than outer; 1 transverse row of minute setules present on ventral surface in the middle of segment (Fig. 2G, arrow); intercoxal sclerite between right and left P5 absent.

Male. Body 530±20 μm (N=5) in length. Sexual dimorphism shown in A1, endopods of P2-P3 and P5. A1 subchirocerate, 6-segmented; geniculate between segments 4 and 5; segment 4 enlarged, bearing 1 long aesthetasc; last segment small, with 8 bare setae distally.

P2-P4 (Fig. 3C-E), exopod 3-segmented, endopod 2-segmented. P2-P3, enp 1 lacking inner seta; enp 2 bearing 1 outer spine, 2 long plumose setae distally and 1 modified, spiniform inner proximal seta (Fig. 3D, arrow). P4 enp 1 with inner distal corner produced.

P5 (Fig. 2H) small, shaped as 1 pentagonal plate, connected with each other by small plate; bearing 4 bare setae in total on outer distal edge; inner margin convex without spinule or setule ornamentation.

Distribution. Europe (North Sea, Atlantic coasts of France and U.K., Mediterranean Sea, Black Sea), North Africa (Algeria, Egypt), Israel, Iran, China, Korea, Japan, America (U.S.A., El Salvador, Brazil).

Remarks. In the genus *Leptocaris* T. Scott, 1899, more than 24 species have been recorded so far (Boxshall and Halsey, 2004). Among them, three species share the characteristics of P2-P3 exp 3 with 5 setae/spines, P4 enp 2 with 4 setae/spine, and inhabiting brackish waters: *L. brevicornis* (van Douwe, 1904), *L. trisetosus* (Kunz, 1935), and *L. sibiricus* Borutzky, 1952.

Leptocaris brevicornis is one of the most famous and widely distributed species in this genus. It differs from *L. trisetosus* by the character combination as follows: (1) P5 is armed with 2 setae in female and 4 setae in male, while 3 and 6 setae, respectively, in *L. trisetosus*; (2) basal part of terminal caudal seta is normal, while swollen laterally and spatulate in *L. trisetosus*; (3) madibular palp is absent, against represented by a small protuberance bearing 2 small setae in *L. trisetosus;* (4) P2 enp 1 without inner seta, against with 1 pinnate seta inner distally in *L. trisetosus*.

Leptocaris brevicornis is similar to *L. sibiricus* in having the similar appearance of terminal caudal seta and same setal armature of P5 in both sexes, however, the former is clearly distinguished from the latter by the shape of Fu, that is, it has a lateral seta in distal half of lateral margin, while *L. sibiricus* lacks the lateral seta but with rounded chitinous thickening in proximal part of outer margin (Borutzky, 1952).

Korean specimens fit well with the redescriptions (Borutzky, 1952; Dussart, 1967; Kunz, 1978; Apostolov and Marinov, 1988), except a discrepancy of the presence of minute setule row in the middle of the ventral surface of female P5 (Fig. 2G, arrow). The minute setule row is observed under a differential interference contrast microscope with high resolution power. It is not obvious whether the characteristic was ignored in the previous studies or appeared as the proper one to Korean specimens. Considering the figure of female P5 in Huys et al. (1996) also shows the faint trace of fusion in the middle of medial margin of P5, there is no evident ground that it should be regarded as taxonomically significant enough to designate Korean population for a distinct taxon.

This species is known as euryhaline (Dussart, 1967; Huys et al., 1996), and reported from brackish-waters or freshwaters in the tidal reaches (Tai and Song, 1979), and from saline swamps on the seacoast (Borutzky, 1952). In Korea, this species was collected from sandy mud sediments with high organic content around reed marshes in the estuaries. It co-occurred with *Sinodiaptomus tenellus*, *Pseudodiaptomus inopinus* (Calanoida), *Nitokra koreanus*, *Tachidius parvus*, *Tigriopus japonicus*, *Schizopera neglecta*, *Kollerua longum*, *Onychocamptus vitiospinulosa*, *Apolethon bilobatus* (Harpacticoida), *Paracyclopina nana*, *Halicyclops sinensis*, and *H. japonicus* (Cyclopoida).

[1]**Leptocaris trisetosus pacificus* n. subsp. (Figs. 4, 5)

Type material. Holotype ♀ (NIBRIV0000100282), in ethyl alcohol, Dadaepo (reed marsh; 35°02′50″N, 128°57′53″E), Busan, 28 Sep. 2005 (C.Y. Chang, J.M. Lee and H.W. Lim). Allotype: ♂ (NIBRIV0000100283), in ethyl alcohol, collection detail same as in holotype. Dissected paratypes (1♀, 1♂) are kept in the research collection of the senior author (CYC).

Additional material examined. 1♀, 1♂, Dadaepo (reed marsh), Busan, 26 Oct. 2006 (C.Y. Chang); 3♀♀, 1♂, estuary of Gasancheon Str., Chukdong, Sacheon, 26 Apr. 2007 (C.Y. Chang, J.M. Lee and H.J. Yoon).

Description. *Female*. Body (Fig. 4A) slender, cylindrical, 720±24 μm (ranging 689-753μm, N=4) in length, somewhat longer than the preceding species (*L. brevicornis*), tinged with milky white; body integument much thicker than that of *L. brevicornis*; with nearly parallel lateral mar-

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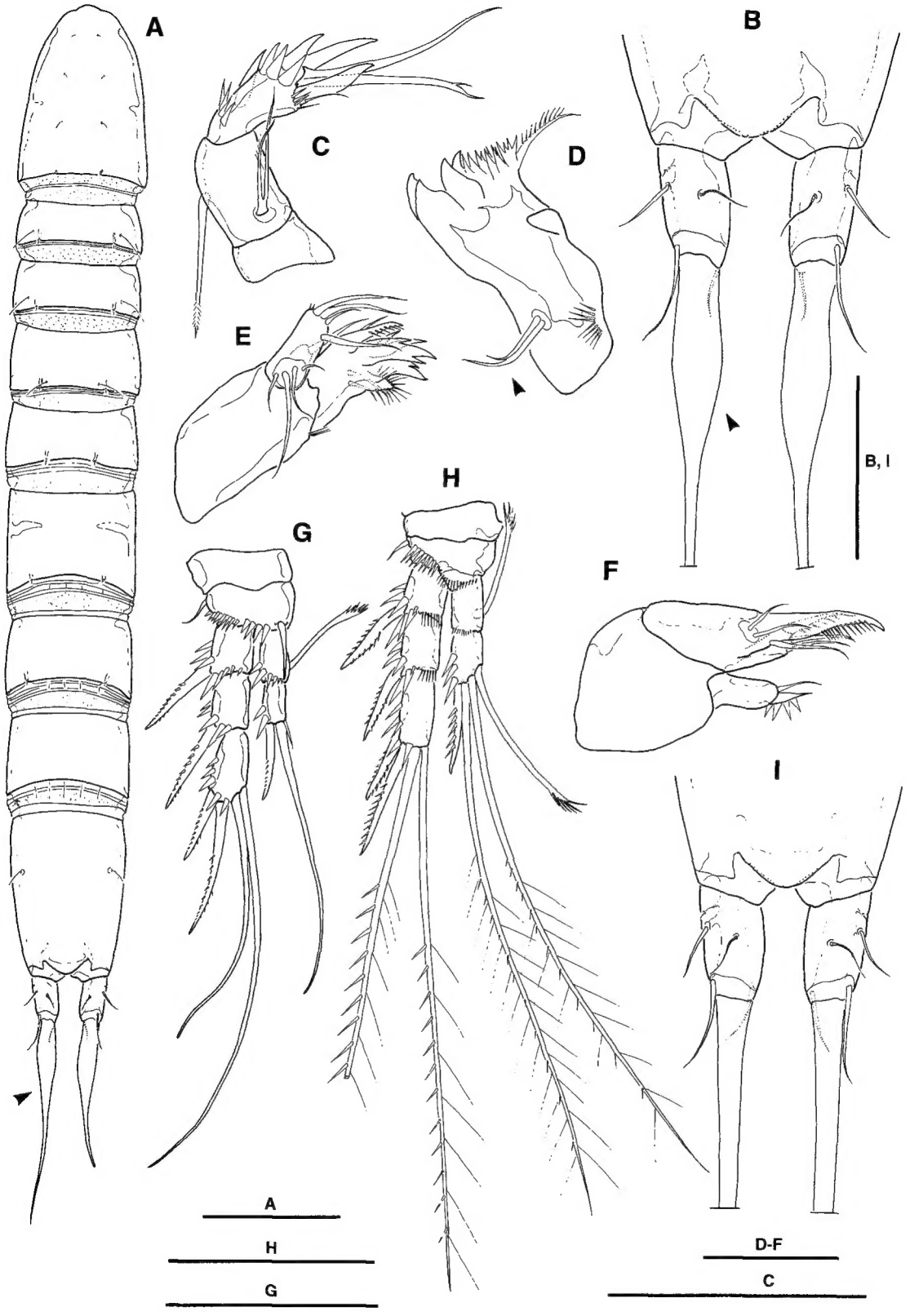

Fig. 4. *Leptocaris trisetosus pacificus n.* ssp. A-H, female: A, habitus, dorsal; B, anal somite and Fu, dorsal; C, A2; D, mandible; E, maxillule; F, maxilla; G, P1; H, P2. I, male anal somite and Fu, dorsal. Scale bars=100 μm (A), 50 μm (B-I).

gins, without clear distinction between prosome and urosome, tapering posteriorly at anal somite. Prosome consisting of cephalothorax and 3 pedigerous somites; urosome of fifth pedigerous somite, genital double-somite, 2 abdominal somites and anal somite. Cephalothorax protruding anteriorly, a little shorter than next 3 prosomites combined; short hairs scattered on dorsal surface. Rostrum not conspicuous. Three pedigerous somites with 2 pairs of sensillae along posterior margin; posterior margins of all somites smooth; outer distal corner not protruded. Genital double-somite without subdivision but with subcuticular ridge marking faint line of fusion (suture) in dorsolateral sides. Anal somite elongate, about 1.5 times longer than wide, with paired sensillae dorsolaterally. Anal operculum convex, with posterior margin finely denticulate (Fig. 4B).

Fu cylindrical, about 1.62 times (mean 1.62, N=4) longer than wide, a little narrowing posteriorly (Fig. 4B). Dorsal surface and medial margin smooth except dorsal or lateral caudal seta. Lateral caudal setae (caudal setae I, II) vestigial, locating at proximal quarter of lateral margin. Outer caudal seta (caudal seta III) slender, locating near proximal third of lateral margin. Outer terminal caudal seta (caudal seta IV) slender, nearly as long as Fu. Inner terminal caudal seta (caudal seta V) 0.2 times as long as body length, 1.3 times longer than anal somite; basal part swollen (Fig. 4A, B, arrow). Inner caudal seta (caudal seta VI) short, 1/3 times as long as outer terminal caudal seta. Dorsal caudal seta (caudal seta VII) locating nearly in middle of dorsal surface.

A1 short, tapering distally, 5-segmented; segment 2 bearing 2 dorsal setae; segments 4 and 5 each with 1 long aesthetasc apically. A2 (Fig. 4C) 3-segmented; free endopod 1-segmented, bearing 7 spines and 2 terminal setae; allobasis with 1 pinnate seta inner distally; exopod vestigial, represented by 1 small protuberance bearing 2 minute setae apically.

Mandibular palp vestigial, reduced to 2 slender setae (Fig. 4D, arrow), coxal gnathobase bearing several bicuspidate teeth along distal margin with 1 pinnate seta at distomedial corner. Maxillule (Fig. 4E) with well developed praecoxal arthrite bearing 5 distal elements including 1 swollen pinnate seta posteriorly, with 2 anterior surface setae; coxa, basis and rami fused to form unsegmented palp bearing 9 setae in total along distal margin. Maxilla (Fig. 4F) armed with 2 syncoxal endites, each bearing 2 elements apically; basis forming 1 strong pectinate claw, flanked by 2 proximal setae; endopod represented by protuberance bearing 2 bare setae. Maxilliped absent.

P1 (Fig. 4G), exopod 3-segmented; endopod 2-segmented; endopod much shorter than exopod; basis with 1 medial seta, nearly reaching tip of enp 1; enp 1 a little longer than enp 2, bearing 1 stout, terminally pinnate inner distal seta, pointing anteromedially; enp 2 with 1 short inner distal seta, 1 long apical seta and 1 outer spine; exp 2 without inner seta; exp 3 with 1 outer spine, 1 pinnate outer distal seta and 2 long setae.

P2-P4 (Figs. 4H, 5A, B), exopods 3-segmented; endopods 2-segmented. P2, enp 1 with 1 terminally pinnate seta inner distally, pointing usually inner proximally; enp 2 bearing 1 outer distal spine, 2 long apical setae (nearly similar in length to each other), 1 terminally pinnate inner seta. Seta and spine arrangements of P1-P4 as follows (Arabic numerals representing setae, while Roman numerals indicating spines):

P1	basis 1-1	exp I-0; I-0; I,2,1	enp 0-1; I,1,1
P2	basis 1-0	exp I-0; I-0; II,2,0	enp 0-1; I,2,1
P3	basis 1-0	exp I-0; I-0; II,2,1	enp 0-0; I,2,1
P4	basis 1-0	exp I-0; I-0; II,2,1	enp 0-0; I,2,1

P5 (Fig. 5C) small, represented by small plate with 3 bare setae distally; median seta conspicuously short; inner seta about 1.8 times longer than median seta, 0.7-0.8 times as long as outer seta.

Male. Body cylindrical, 640±20 μm (N=3) in length. Sexual dimorphism shown in terminal caudal seta, A1, and P5. Endopods of P2-P4 basically not exhibiting sexual dimorphism, except for 1 additional inner distal seta on P3 enp 2. Terminal caudal seta normal (Fig. 4I), its basal part not swollen laterally as in female's. A1 subchirocerate, 6-segmented; geniculate between segments 4 and 5; segment 4 enlarged, bearing 1 long aesthetasc; last segment small, with 8 bare setae distally.

P2-P4, exopod 3-segmented, endopod 2-segmented. P2 enp 1 (Fig. 5D) with 1 terminally pinnate seta inner distally; enp 2 bearing 1 outer distal spine, 2 long plumose apical setae and 1 terminally pinnate inner distal seta. P3 enp 1 lacking inner seta; enp 2 with 1 additional spiniform inner distal seta (Fig. 5E, arrow). P4 enp 1 (Fig. 5F) lacking inner seta; enp 2 bearing 1 outer spine, 2 long plumose apical setae and 1 terminally pinnate seta inner distally.

P5 (Fig. 5G) well developed, forming wing-like plate; right and left P5 confluent basally; bearing 2 big spiniform setae medially (Fig. 5G, arrow) with 4 bare setae on lateral edge.

Etymology. The proposed subspecific name, '*pacificus*', alludes to the geographical distribution where the new subspecies exhibits, against the nominate subspecies restricted to the Atlantic coasts.

Remarks. Comparing with *L. brevicornis*, *L. trisetosus* has been found rather rarely, and its geographical distribution is shown as somewhat scattered along both sides of the Atlantic, *viz*. Germany (Kiel), Finland, France (Atlantic coast), Bahama and South Africa (*see* Kunz, 1978, fig. 2).

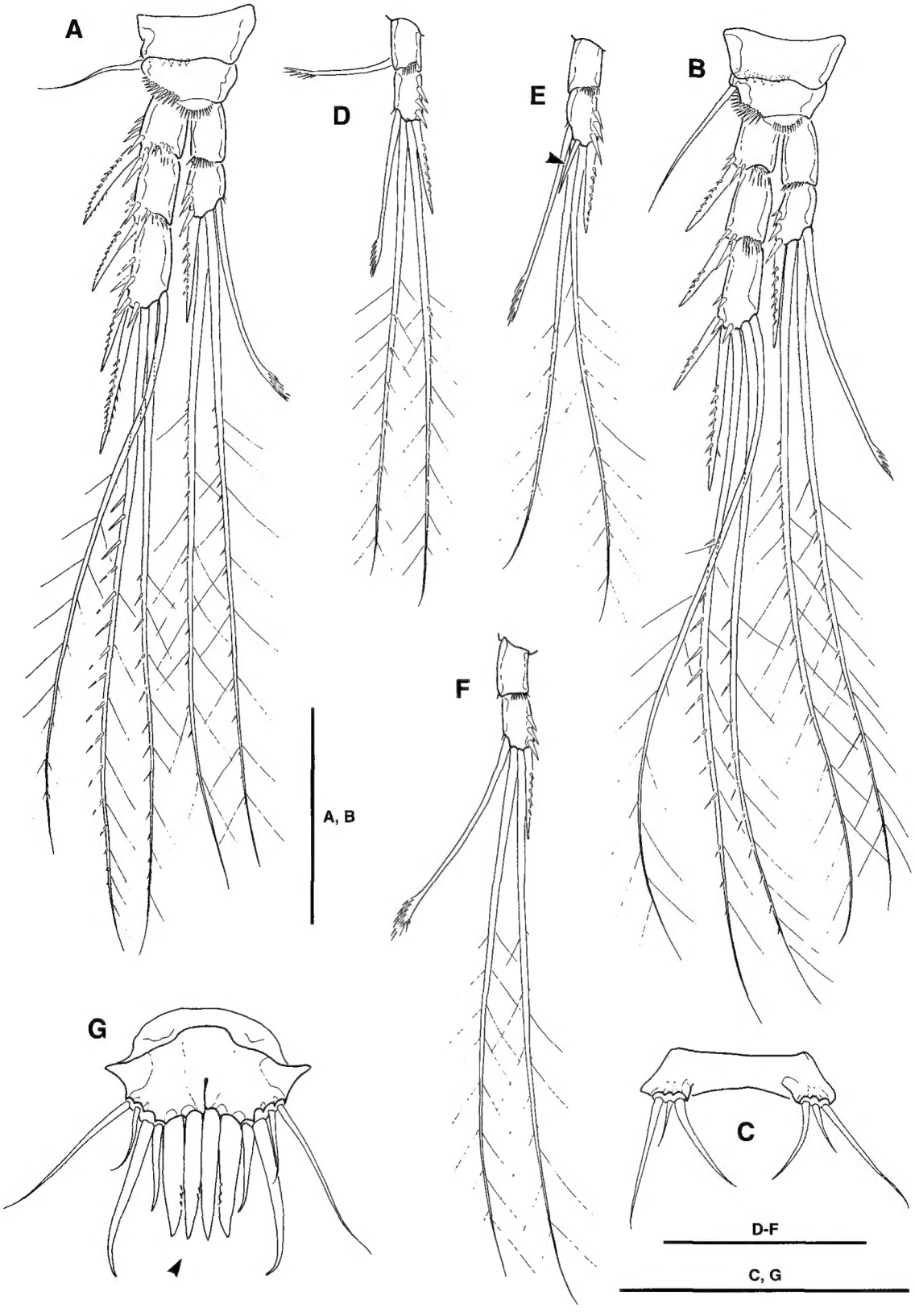

Fig. 5. *Leptocaris trisetosus pacificus* n. ssp. A-C, female: A, P3; B, P4; C, P5. D-G, male: D, P2 endopod; E, P3 endopod; F, P4 endopod; G, P5. Scale bars=50 μm (A-G).

As mentioned in the 'Remarks' section of the preceding species (*L. brevicornis*), *L. trisetosus* most resembles *L. brevicornis* and *L. sibiricus* Borutzky in having the similar armature of female P2-P3 exp 3 with 5 setae/spines and P4 enp 2 with 4 setae/spine, and inhabiting brackish waters. *Leptocaris trisetosus* is characteristic in having the spatulate basal part of terminal caudal seta in the female, and the peculiar P5 shaped as wing-like plate with spiniform inner setae in the male (Kunz, 1935).

Although males have been unknown or inadequately described in many species of *Leptocaris*, two different trends can be apparently recognized whether sexual dimorphism exists in the seta/spine armature of P2-P3 endopods or not. In one group such as *L. brevicornis* and *L. minimus* (Jakobi), the setae on P2-P3 endopods, especially on P3 enp 2, are conspicuously modified into spiniform projections (*see* Fig. 3C, D; Kunz, 1978, fig. 16), while in the other group such as *L. trisetosus* and *L. kunzi* Fleeger and Clark, the armature is exactly same or much similar to each other between sexes (*see* Fig. 5D, E; Fleeger and Clark, 1980).

Korean population coincides well with the *L. trisetosus s. str.*, except for the setal armature of P3 enp 2, that is, bearing an additional inner seta in the male (*see* Fig. 5E, arrow). According to Borutzky (1952) and Dussart (1967), *L. trisetosus s. str.* from the Atlantic coasts does not exhibit the sexual dimorphism in the seta/spine armature of P2-P4 endopods. As the partial modification on the male P3 endopod occurs in Korean population, and its geographical distribution is allopatric to that of *L. trisetosus s. str.*, we tentatively accommodate the Korean population as a subspecific status, pending the more extensive studies on the *Leptocaris* in the future.

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